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Introduction: Over the next decade, international plans and commitments are underway to develop an infrastructure at Mars to support future exploration of the red planet. The purpose of this infrastructure is to provide reliable global communication and navigation coverage for on-approach, landed, roving, and in-flight assets at Mars. The claim is that this infrastructure will: 1) eliminate the need of these assets to carry Direct to Earth (DTE) communications equipment, 2) significantly increase data return and connectivity, 3) enable small mission exploration of Mars without DTE equipment, 4) provide precision navigation i.e., 10 to 100m position resolution, 5) supply timing reference accurate to 10ms. [1]. This paper in particular focuses on two CCSDS recommendations for that infrastructure: CCSDS Proximity-1 Space Link Protocol [2] and CCSDS File Delivery Protocol (CFDP)[3]. A key aspect of Mars exploration will be the ability of future missions to interoperate. These protocols establish a framework for interoperability by providing standard communication, navigation, and timing services. In addition, these services include strategies to recover gracefully from communication interruptions and interference while ensuring backward compatibility with previous missions from previous phases of exploration. [4].

Need for Standardization: The diversity of communication links within the future potential Mars environment creates challenging engineering problems. Problems such as frequency coordination, link operations, standard data transfer, product accountability, link performance, scheduling vs demand access of services, and network-wide data prioritization need to be addressed. The CCSDS Proximity-1 Space Link Protocol provides recommendations for dealing with the components of these issues in the physical and data link layers. These include frequency allocation, coding, data rates, link establishment, maintenance, and termination procedures, reliable or expedited data transfer, ranging and time transfer. On top of Proximity-1, the CCSDS File Delivery Protocol at the transport layer provides applications the capability of transporting their data products end to end across the entire space link either expedited or reliably.

Proximity-1 Key Characteristics: Proximity-1 provides standard services for transferring command, telemetry, and radiometric data products across the In-Situ link. It provides a timing service which includes techniques for round trip light time (RTLT) calculation and setting remote spacecraft time. It also provides a messaging service between In-Situ assets. Proximity-1 is a bi-directional protocol using the same format and procedures in the forward (command) as well as the return (telemetry) link. It provides for expedited as well as reliable data transfer. It is truly a modeless protocol meaning all of the services provided do not require that the caller or responder be configured into a particular mode for operations. It supports all types of directionality: full, half duplex, and simplex. It uses a data driven technique as opposed to a managed approach for on-board data processing. It supports both coded and uncoded links as well as asynchronous (variable frame) vs synchronous (fixed frames) links. Communication is point-to-point but includes one to many on the forward link.

CFDP Key Characteristics: CFDP is an international standard for automatic, reliable or expedited bidirectional file transfer between spacecraft or spacecraft and ground, built on top of the CCSDS data link layer. Unlike TCP/IP, it requires no handshaking and is datagram and transaction based to deal with space link characteristics e.g., long RTLT and non-persistent links but is adaptable to fit the proximity link as well. Metadata associated with each transaction describes the data transfer including data processing once the file arrives.

Operational Scenarios: The following scenarios examine operations across two separate links: proximity (landed assets to orbiters) and deep space (orbiters to Earth). The proximity link is characterized by short distance (within 400,000 km), moderate signal strength, and single sessions. The deep space link is characterized by long delays, and weak signals. The following 5 scenarios generically demonstrate operations between Mars landed assets, orbiter relays, and Earth ground stations.

Scenario 1: Simple Relay.

Scenario 2:Multi-Hop Relay (Rover to lander to orbiter to Earth)

Scenario 3:Point-to-Multi-point (forward link

Scenario 4:Time-Sequenced Point-to-Point (return link)

Scenario 5:Point-to-Point Network

Transition Plan for Protocol Infusion: The NASA/JPL Mars 2001 orbiter and ESA Mars Express/Beagle II project will be the first Mars missions to implement a subset of Proximity-1 for the In-Situ

Martian UHF link. In order for these and future Mars missions to benefit from all the advantages of file transfer, a step wise transition from the current state of on-board protocol development to a complete implementation of Proximity-1 and CFDP is envisioned. A three phased approach below describes how the bi-directional file transfer concept can be infused into future Mars missions.

Phase 1:Expedited CFDP (Deep Space Link)/reliable Proximity-1 Link

Phase 2: Expedited CFDP (In-Situ and Deep Space)/reliable Proximity-1 Link

Phase 3: Reliable CFDP (In-Situ and Deep Space)/ unreliable Proximity-1 Link.

References: [1] Hastrup, R.C. "Mars Network for Enabling Low-Cost Missions," Fourth IAA International Conference on Low-Cost Planetary Missions," IAA-L-0509, Laurel, Maryland, 2-5 May 2000. [2] Consultative Committee on Space Data Systems Proximity-1 Space Link Protocol, CCSDS 211.0-R-2, Red Book Issue 2, Jan. 2000. Available at http://www.ccsds.org/ .[3] Consultative Committee on Space Data Systems File Delivery Protocol, CCSDS 727.0-R-3, Red Book Issue 3, May 1999. Available at http://www.ccsds.org/ [4] Kazz, G.J. "Application of an Extended CCSDS Telecommand Standard for all Mars In-Situ Telecommunication Links," First ESA Workshop on Tracking, Telemetry, and Command Systems, ESTEC, Noordwijk, Netherlands, June 24-26, 1998.